REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-03-
0317

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 14, 2003	Final Report 1999-2002

4. TITLE AND SUBTITLE
Accurate Now-Casting of Near-Earth Space Conditions from Low-Altitude Satellites

5. FUNDING NUMBERS
F49620-00-1-0172

6. AUTHOR(S)
Patrick T. Newell, Ching-I. Meng, and Simon Wing

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Johns Hopkins University Applied Physics Laboratory
11100 Johns Hopkins Rd.
Laurel, MD 20723

8. PERFORMING ORGANIZATION REPORT NUMBER
FG619-Final

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Office of Scientific Research
015 Wilson Boulevard, Room 713
Arlington, VA 22203-1954

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
Final Report: F49620-00-1-0172

11. SUPPLEMENTARY NOTES
Attached

20030915 026

12a. DISTRIBUTION / AVAILABILITY STATEMENT
No limitations imposed by JHU/APL
Approved for public release, distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 Words)***

Auroral particles have been studied for years using DMSP satellites. The goal of this project was to apply past research to develop practical tools for monitoring the real-time position of the auroral oval (nowcasting), and more generally, monitoring the general state of space weather from DMSP particle data. The effort was successful. A real-time auroral oval monitor (OVATION) was developed, and transitioned to AF space weather operations. The OVATION effort nowcasts the current auroral oval position and intensity, along with the general state of excitation of the near-Earth space conditions ("space weather").

The tools developed in creating OVATION in turn provided new opportunities for basic research. One important finding which resulted is that a seasonal variation in space weather intensity exists, which depends primarily on whether the nightside auroral oval of either the northern or southern hemisphere is sunlit.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Space weather, aurora, real-time monitor	
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	none

FINAL TASK REPORT: F49620-00-1-0172

Research Title: Accurate Now-Casting of Near-Earth Space Conditions from Low-Altitude Satellites

Principal Investigator: Patrick T. Newell

Commercial Phone: (240) 228-8402 FAX: (240) 228-6670

Mailing Address: Johns Hopkins University Applied Physics Laboratory

11100 Johns Hopkins Rd.

Laurel MD, 20723

E-Mail Address: Patrick.Newell@jhuapl.edu

AFOSR Program Manager: Maj. Paul Bellaire

Research Objectives as Originally Proposed:
To characterize the magnetosphere-ionosphere system more accurately in terms of state variables, such as polar cap flux and magnetotail stretching. These state variables can be computed from DMSP particle precipitation data. In addition to developing and validating these state variables, which improve the art of "nowcasting" the magnetosphere, an additional goal is to develop short term (~1 hour) forecasting ability, especially as regards to monitoring the auroral oval.

Summary:

Auroral particles have been studied for years using DMSP satellites. The goal of this project was to apply past research to develop practical tools for monitoring the real-time position of the auroral oval (nowcasting), and more generally, monitoring the general state of space weather from DMSP particle data. The effort was successful. A real-time auroral oval monitor (OVATION) was developed, and transitioned to AF space weather operations. The OVATION effort nowcasts the current auroral oval position and intensity, along with the general state of excitation of the near-Earth space conditions ("space weather").

The tools developed in creating OVATION in turn provided new opportunities for basic research. One important finding which resulted is that a seasonal variation in space weather intensity exists, which depends primarily on whether the nightside auroral oval of either the northern or southern hemisphere is sunlit.

(1) Research Results

The most extensive discussion of our research results is naturally to be found in the papers published in scientific journals
over the last year (see the list below). The most important research findings in terms of understanding space weather (the
main goal of this AFOSR grant) are as follows.

A. Seasonal and Diurnal Variations in Space Weather

It has been known for more than a century that auroral activity is most common around equinoxes. More generally,
geomagnetic activity as represented by commonly used indices shows seasonal and diurnal variations. An understanding
of these variations is clearly a pressing need for space weather forecasting and nowcasting.

In a paper published in JGR [*Newell et al.*, 2002], we presented several findings which improve understanding of the seasonal and diurnal variation.
The total ionospheric conductivity in the nightside auroral oval from UV insolation (Σ_P) was calculated, and its seasonal and
diurnal variation was shown to correlate very highly with that of the Am and AL indices of geomagnetic activity (r=0.89 and
r=0.75 respectively). The level of geomagnetic activity is well-ordered by whether the nightside auroral oval is sunlit in
one hemisphere or neither.

We improved calculations of the expected pattern of seasonal and diurnal variations in the solar wind input. The elliptical nature of the Earth's orbit results in observed interplanetary magnetic field (IMF) strengths about 7% larger in January than June. When the sun's spin axis tilt to the ecliptic plane is considered, the predicted IMF southward component (Bs) maximizes in February, as is observed. We also calculate the seasonal and diurnal variation of a more general solar wind-magnetosphere coupling function, E_{KL}. E_{KL} proves to have very little (0.5%) diurnal variation, and has a seasonal variation of about 14%.

For the first time, the seasonal and diurnal variation in Φ_{PC}, the polar cap flux (from Polar UVI observations, cross-calibrated to a DMSP-based standard) and in magnetotail stretching (the b2i index) are presented. Magnetotail stretching proves to correlate better (r=-0.57) with E_{KL} than with Σ_P. Φ_{PC} correlates better with Σ_P, but the correlation (r=0.49) is not nearly so strong as for the indices of geomagnetic activity, Am and AL. Our survey of the seasonal and diurnal variation of the magnetosphere thus shows that some aspects (geomagnetic indices) correlate best with UV insolation, while others (magnetotail stretching) correlate best with solar wind input.

B. Source of Plasma in the Magnetotail

Plasma in the magnetosphere ultimately is supplied by either the ionosphere or the solar wind. However it often been difficult to pin down the relative contributions, and especially, the supply route, i.e., the proximate source of solar wind plasma entering the magnetotail. Observations funded by this AFOSR Grant have provided a powerful clue about the source of the magnetotail plasma. DMSP observations mapped to the magnetotail show a cold, dense plasma inside the magnetotail, along the flanks (adjacent to the Low-Latitude Boundary Layer). The cold dense region is more evident for northward IMF, when the LLBL is thicker, than for southward IMF. These observations clearly point to the LLBL as a major source for the plasma sheet. (That is, solar wind plasma enters into the magnetotail via the LLBL). Papers describing these findings have been published in *J. Geophys. Res.* and *Geophys. Res. Lett.,* (see Wing and Newell papers for 2001 and 2002 in reference list).

(2) Practical (Operational) Results

A. Monitor of the Auroral Oval (OVATION)

A major goal of this grant was to develop, and make practical the real-time monitoring the auroral oval position, intensity, and variations. Since no one data source can provide such global, continuous, and real-time coverage, our approach is to use the DMSP data base as a standard, and to cross-calibrate other data sources to the DMSP standard. The auroral project is named OVATION, for (auroral) Oval Variation, Assessement, Intensity, and Online Nowcasting. An early version of the project, using DMSP data only, and concerned only with the oval boundaries, was delivered to the AF Space Weather operations in Colorado Springs (Kevin Scro). In 2001, we cross-calibrated the DMSP to several additional data sets, notably a Meridian scanning photometer (MSP) in Fairbanks, Alaska, the NASA Polar UVI data, and the SuperDARN radars. In 2003, the AF space weather effort in Oklahoma is attempting another transition of OVATION (an effort with which we cooperate on a no-cost basis), although the real-time system continues to operate at APL. The fully operational system can be seen here:

http://sd-www.jhuapl.edu/Aurora/ovation_live/north_display.html

Our development effort has been helped by several synergies. Notably, future DMSP satellites will include a UV imager built at APL. This has helped in our efforts to obtain DMSP data real-time (from AF Space Weather operations). Likewise, some of the cross-calibration effort involving other instruments has been funded by the UPOS effort. However the largest single contribution to the OVATION project, by far, has come from this AFOSR grant.

We regard the creation of an ongoing real-time auroral oval monitor as a significant benefit to AF space weather operations, as well as to the general scientific community.

Publications:

Published in Peer Reviewed Journals and Books

1. Jayachandran, P. T., J. W. MacDougall, J.-P. St-Maurice, D. R. Moorcroft, P. T. Newell, and P. Prikryl, Coincidence of the ion precipitation boundary with the HF E region backscatter boundary in the dusk-midnight sector of the auroral oval, *Geophys. Res. Lett., 29,* 10.1029/2001GL014184, 2002.
2. Jayachandran, P. T., J. W. MacDougall, D. R. Moorcrot, J.-P. St-Maurice, K. Liou, and P. T. Newell, *Geophys. Res. Lett., 29,* 10.1029/2002GL015484, 2002.
3. Kubyshkina, M. V., V. A. Sergeev, S. V. Dubyagin, S. Wing, P. T. Newell, W. Baumjohann, and A. T. Y. Lui, Constructing the magnetospheric model including pressure measurements, *J. Geophys. Res., 107,* 10.1029/2001JA900167, 2002.
4. Liou, K., C.-C. Wu, R. P. Lepping, P. T. Newell, and C.-I. Meng, Midday sub-auroral patches (MSPs) associated with interplanetary shocks, *Geophys. Res. Lett., 29,* 10.1029/2001GL014182, 2002.
5. Liou, K., C.-I. Meng, A. T. Y. Lui, P. T. Newell, and S. Wing, Magnetic dipolarization with substorm expansion onset, *J. Geophys. Res., 107,* 10.1029/2001JA00179, 2002.
6. Lu, G., T. E. Holzer, D. Lummerzheim, J. M. Ruohoniemi, P. Stauning, O. Troshichev, P. T. Newell, M. Brittnacher, and G. Parks, Ionospheric response to the IMF southward turning: Fast onset and slow reconfiguration, *J. Geophys. Res., 107,* 10.1029/2001JA000324, 2002.
7. Liou, K., P. T. Newell, and C.-I. Meng, Seasonal effects on auroral particle acceleration and precipitation, *J. Geophys. Res., 106,* 5531-5542, 2001.
8. Lyatsky, W., P. T. Newell, and A. Hamza, Solar illumination as cause of the equinoctial preference for geomagnetic activity, *Geophys. Res. Lett., 28,* 2353-2356, 2001.
9. Meng, C.-I., K. Liou, and P. T. Newell, Asymmetric sunlight effect on dayside/nightside auroral precipitation, *Phys. Chem. Earth (C) 26,* 43-47, 2001.
10. Newell, P. T., Rhythms of the auroral dance, *Nature, 414,* 2001.
11. Newell, P. T., R. A. Greenwald, and J. M. Ruohoniemi, The role of the ionosphere in aurora and space weather, *Rev. Geophys., 39,* 137-149, 2001.
12. Newell, P. T., C.-I. Meng, T. Sotirelis, and K. Liou, Polar Ultraviolet Imager observations of global auroral power as a function of polar cap size and magnetotail stretching, *J. Geophys. Res., 106,* 5895-5905, 2001.
13. Newell, P. T., T. Sotirelis, J. P. Skura, C.-I. Meng, and W. Lyatsky, Ultraviolet insolation drives seasonal and diurnal space weather variations, submitted to *J. Geophys. Res.,* 2001.
14. Newell, P. T., T. Sotirelis, J. P. Skura, C.-I. Meng, and W. Lyatsky, Ultraviolet insolation drives seasonal and diurnal space weather variations, *J. Geophys. Res.,107,* 10.1029/2001JA00029610, 2002.
15. Newell, P. T., T. Sotirelis, J. F. Carbary, K. Liou, J. P. Skura, C.-I. Meng, C. Deehr, D. Wilkinson, and F. J. Rich, OVATION: Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting,, *Annales Geophysicae, 20,* 1039-1047, 2002.
16. Newell, P. T., K. Liou, J. P. Skura, and C.-I. Meng, The distribution of auroral power increases and decreases, *Geophys. Res. Lett. 29,* 10.1029/2002GL016288, 2002.

---Newell, P. T., and T. G. Onsager, Laissez-Rouler Le Bon LLBL, (Meeting Report), *EOS, 83,* 3, 2002.

17. Pitout, F., P. T. Newell, and S. Buchert, Simultaneous high- and low-latitude reconnection: ESR and DMSP observations, *Annales Geophysicae, 20,* 1311-1320, 2002.
18. Shue, J.-H., P. T. Newell, K. Liou, C.-I. Meng, and S. W. H. Cowley, Interplanetary magnetic field B_x asymmetry effect on auroral brightness, *J. Geophys. Res. 107,* 10.1029/2001JA000229, 2002.
19. Shue, J.-H., P. T. Newell, K. Liou, C.-I. Meng, Y. Kamide, and R. P. Lepping, Two-component auroras, *Geophys. Res. Lett., 29*(10), 10.1029/2002GL014657, 2002.
20. Shue, J.-H., P. T. Newell, K. Liou, and C.-I. Meng, Solar wind density and velocity control of

auroral brightness under normal interplanetary magnetic field conditions, *J. Geophys. Res., 107,* 10.1029/2001JA009138, 2002.
21. Troshichev, O., P. T. Newell, M. Brittnacher, G. Parks, Ionospheric response to the interplanetary magnetic field southward turning: Fast onset and slow reconfiguration, *J. Geophys. Res.,* 10.1029/2001JA000324.
22. Vaivads, A., M. André, S. Buchert, A. Eriksson, A. Olsson, J.-E. Wahlund, P. Janhunnen, G. Marklund, L. M. Kistler, C. Mouikis, D. Winningham, A. Fazakerley, and P. Newell, What high altitude observations tell us about the auroral acceleration: a Cluster/DMSP conjunction, (in press) *Geophys. Res. Lett.,* 2002.
23. Wing, S., and P. T. Newell, 2D plasma sheet ion density and temperature profiles for northward and southward IMF, 10.1029/2001GL013950 *Geophys. Res. Lett.*, 2002.
24. Wing, S., P. T. Newell, and J. M. Ruohoniemi, Double cusp: Prediction and model verification, *J. Geophys. Res., 106,* 25571-25088, 2001.

Books: ***Earth's Low Latitude Boundary Layer,*** P. T. Newell and T. G. Onsager, eds., American Geophysical Union, Washington, D.C., 2003.

Invention Disclosures and Patents Granted: None

Invited Lectures, Presentations, Talks, etc.:
Because of our high publication rate in refereed journals, we do not keep a tally of talks.

Professional Activities (editorships, conference and society committees, etc.):
I am editing a book which the American Geophysical Union will publish in 2002, namely *The Low-Latitude Boundary Layer*.

Honors Received (include lifetime honors such as Fellow, honorary doctorates, etc., stating year elected): None

Extended Scientific Visits From and To Other Laboratories: None

Invention Disclosures: None

Appendix C: Technology Transitions/Transfers Detailed Listing

Performer *(name, telephone, and organization)*	**Customer(s)** *(name and organization)*	**Research Result** *(scientific statement)*	**Application** *(technical benefit(s) and/or customer useB List and underline any military applications first)*	Transitioned To	Transitioned From	Application
Patrick Newell Johns Hopkins 240 228-8402	Kevin Scro, AF Colorado Springs Peterson AFB	Auroral Oval real time monitor,	High-latitude navigations, and high-latitude communications forecasting (AFWA)	AF	A	Pd
Patrick Newell Johns Hopkins 240 228-8402	Kevin Scro, AF Colorado Springs Peterson AFB	AACGM (PACE) coordinate system for ordering high-latitude observations	High-latitude navigations, and high-latitude communications forecasting (AFWA)	AF	A	Pd

Note: In the last three columns enter the following codes:

Transitioned From:	Transitioned To:	Application:
AFRL = L	Industry = I	Product (New or Improved) = Pd
Industry = I	Air Force 6.2 or 6.3 = AF	Process (New or Improved) = Pc
Academia = A	Other AF, DoD, or Government = O	Other Technology Benefit = O